HAWAII AGRICULTURAL EXPERIMENT STATION.

J. G. SMITH, SPECIAL AGENT IN CHARGE.

BULLETIN No. 9.

# CITRUS FRUITS IN HAWAII.

BY

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UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

*U. S. Department of Agriculture.*

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1905.

## HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

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# LETTER OF TRANSMITTAL.

HONOLULU, HAWAII, *September 1, 1905.*

SIR: I have the honor to transmit herewith a paper on Citrus Fruits in Hawaii, prepared by Mr. J. E. Higgins, horticulturist of this station, which I respectfully recommend for publication as Bulletin No. 9 of the Hawaii station.

Respectfully,

JARED G. SMITH,
*Special Agent in Charge.*

Dr. A. C. TRUE,
*Director, Office of Experiment Stations,*
*U. S. Department of Agriculture, Washington, D. C.*

Recommended for publication.

A. C. TRUE,
*Director.*

Publication authorized.

JAMES WILSON,
*Secretary of Agriculture.*

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# CITRUS FRUITS IN HAWAII.

## INTRODUCTION.

Citrus fruits were introduced into Hawaii more than a century ago. In the record of Vancouver's voyages it is recorded that in the year 1792 that explorer gave to one of the Hawaiian chiefs in Kona "some vine and orange plants" besides other valuable plants and seeds. A few days later "some orange and lemon plants that were in a flourishing state" were landed on the island of Niihau. These oranges were probably from Tahitian seed, since Vancouver sailed from Tahiti to these islands and records having received large supplies from the natives before his departure. Even earlier attempts at the introduction of the orange and the lime are reported, but it is difficult to say which of the efforts was first successful. Some of the oldest orange trees in the islands are said to have been in a flourishing condition a few years ago at the residence of the late Thomas Brown, esq., on Kauai.

Oranges, lemons, limes, and pomelos have all found a congenial home in Hawaii. Indeed, the orange is sometimes thought of by the casual observer as being indigenous, so eminently suitable have the soil and climate proved to be.

When properly cared for and fertilized some of the native orange trees produce fruits unexcelled in point of flavor and juiciness, bearing little resemblance to the very indifferent specimens often found in the markets, which have been picked green, dumped into casks without curing, and sent into the market.

These facts are in striking contrast with the statistics,[a] showing that between $50,000 and $60,000 worth of citrus fruits were imported into Honolulu alone in the year ended January 27, 1905. Considerable quantities have also arrived at the ports of Hilo and Mahukona direct from San Francisco. These circumstances have seemed to make it desirable to give a statement of common practices in citrus culture, with special reference to their application to Hawaiian conditions.

[a] Mr. C. J. Austin, who, in his capacity of assistant to Mr. Alexander Craw in the entomological department of the Territorial bureau of forestry and agriculture, has had excellent opportunities to keep an accurate account of all fruit importations, has kindly furnished the writer with the figures given. The values are taken from the average price of the fruits in the San Francisco markets. The figures would be much larger if the Honolulu prices were made the basis of the calculations.

## THE ORANGE.

The orange is king of the citrus fruits. It may be treated as a type representing the other members of the group in many particulars relating to soils and cultural methods. In some respects special treatment is required for lemons, limes, and pomelos, as described in the sections devoted to these fruits.

### SOIL.

The orange will grow successfully in a great variety of soils, yet there are a few essential characteristics of a good orange soil which can not be overlooked with safety by the prospective grower. The soil must be abundantly moist but must allow good drainage. It should be deep and rich. It is best to avoid the extremes of heavy and loose texture, though some very heavy soils have given excellent results, particularly when overlaid by a stratum of lighter character. Shallow soils and those underlaid with hard pan near the surface are unsuited to orange culture.

### PREPARATION OF THE SOIL.

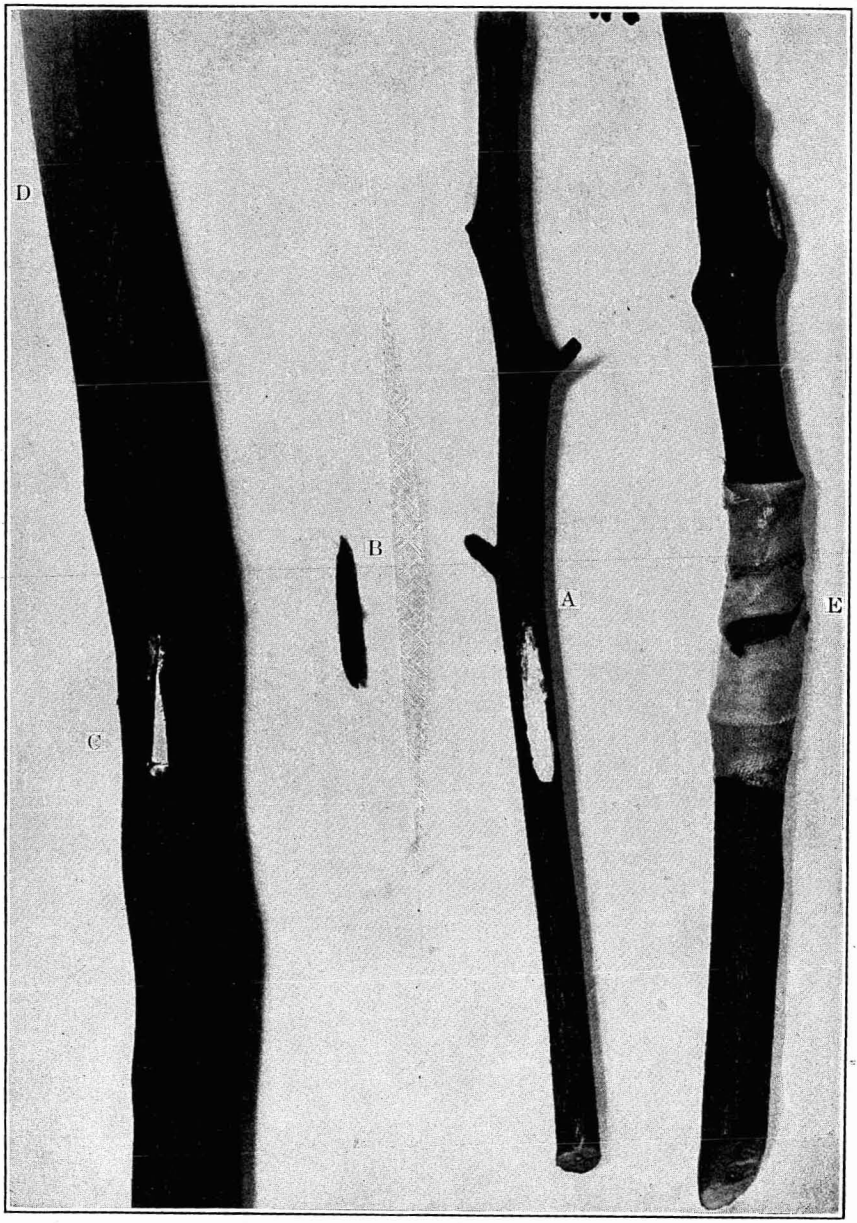
The orange makes very indifferent success of the "hole-in-the-grass" method of cultivation. Where the space is too limited to admit of anything like orchard cultivation the orange will often grow and produce fair fruit, but if a serious attempt is made to grow more than one or two trees they should be placed where their rights to full possession of the soil immediately surrounding them will not be disputed by grass, weeds, or other trees. The first step, then, in preparation is to clear the land, if it be occupied by any other trees. If the soil be virgin it would be well to plant some other crop for a year or two, plowing it deeply and keeping it in good tilth. It is important that the soil be worked deeply, for otherwise the trees, when set out, are likely to form surface rather than deep-feeding roots. Surface-rooted plants suffer much from dry weather. Plow deeply, harrow thoroughly, and get the ground in as friable a condition as possible.

### PROPAGATING THE PLANTS.

The trees may be procured from nurserymen or they may be propagated by the orchardist. If the latter plan is adopted there are several means at hand for reproducing the orange or other citrus trees.

#### SEEDS.

The easiest method of propagation is by seed, but this plan is unsatisfactory when used alone. The seeds of these, as of many other plants, can not be relied upon to reproduce the variety from which they are taken, and for this and other reasons the seedling orange has ceased




SHIELD BUDDING BY THE INVERTED "T" METHOD.

A, Bud wood; B, bud removed from A; C, incisions made in the stock for receiving the bud; D, the bud inserted; E, the bud tied with waxed cotton.

to be desirable as a commercial fruit. Almost any seedling sweet orange, given proper care and cultivation, will produce fruit that is edible, but seedlings have no uniformity as to size, thickness of rind, flavor, number of seeds, or other essential characteristics. Occasionally a tree is found producing fruit which combines the elements of a good merchantable orange, but such cases are rare. Seed propagation must, for the reasons given above, be supplemented by budding and grafting. This consists essentially in placing a small part of a tree of a known variety in such contact with the seedling tree that it unites with the latter. Then, by removing all of the original tree above the point of union, this small part which is inserted grows until it forms a new top for the tree. It must be distinctly understood that the bud or scion inserted does not convert any remaining parts of the former tree top into the new variety. Budding is not inoculation, as some have supposed.

In growing the seedling trees which are to be budded the seeds may be started in an open seed bed or in deep boxes. In any case the soil should be well drained and friable and should be made fairly rich, preferably by the use of commercial fertilizers, applied two or three weeks before planting. The seeds should be planted while fresh and should not be allowed to dry out. If it is desired to hold them for some time before planting they may be preserved by burying deeply in moist sand. If large numbers of seeds are desired the fruits may be allowed to decay and the seeds washed out later through a sieve. The seed may be planted not more than 1 inch deep, in rows 3 or 4 inches apart, or wider if it is desired to keep them clean with the hoe. They will not germinate for about six weeks. When they have made a growth of about 6 inches they may be removed and placed in nursery rows, where the soil has been well prepared and fertilized. In the nursery the plants may stand 12 to 18 inches apart, in rows 4 to 6 feet apart. Keep the ground well tilled, moist, and rich enough to produce a vigorous, steady growth. At about two years from seed the young trees will be large enough to bud, and a year or two later may be dug up and set out in the orchard or grove.

### BUDDING AND GRAFTING.

There are several methods of budding and grafting citrus trees, but that most commonly used is known as "shield" budding. This is illustrated in Plate I. Select budding wood, bearing well-matured buds and not more than 1 year old, but old enough to have lost the angular form characteristic of the youngest orange wood. It is best to cut these pieces from the tree of the desired variety when it is dormant and preserve them until the stocks[a] into which they are to be set

[a] The tree or branch upon which a bud is to be set.

are in a proper condition. They may be preserved by placing them in a box in slightly moistened sawdust and burying the box 6 to 10 inches deep in a shady place in the soil. The leaves should first be removed.

When the stocks are dormant the bark can not easily be separated from the wood, but when they have commenced to make a new growth, which they do several times during the year, the buds may be set. In this frostless climate it is well to set the bud several inches above the ground. At such a point make a vertical slit in the bark of the stock about 1½ inches long, and at the lower end of this make a horizontal incision with the edge of the knife turned slightly upward. Taking the bud wood in the left hand, place the knife about half an inch below a bud and make a shallow cut, removing the bud with about 1 inch of bark. Now, with the knife raise the corners of the bark on the stock where the two incisions were made, and, being careful not to invert the bud, insert it, pushing it up the vertical slit. When in place, bind it snugly, but not too tight. One of the best tying materials is muslin which has been saturated with grafting wax.[a] Simply bind it about the stock, covering all the incisions but not the bud, and so lapping it that it will shed water. It will hold tightly enough without any tying. Unwaxed strips of cotton, candle wicking, raffia, or any such soft material may be used to tie the buds, but the use of the waxed muslin gives extra assurance of success in this climate, where evaporation goes on so rapidly.

About ten days or two weeks after setting the buds examine them to see whether they have united with the stocks. If they are still green and a grayish line of new growth is seen where the incisions were made, it may be concluded that a union has been effected. If so, cut off or partly cut off the stock a few inches above the bud, and the latter will soon begin to grow. The growing shoot may be tied to this remaining part of the stock until it has attained a growth of 12 to 15 inches, at which time it is best to cut off the stock close to the bud with a slanting cut. Then it may be necessary to support the new growth by tying it to a stake, using some soft tying material.

This is known as "shield" budding by the inverted T method. The ordinary T method is more commonly practiced with deciduous trees and is also much used with citrus species. It is precisely the same as the method above described, except that the horizontal incision is

[a] A good receipt for grafting wax is as follows: Resin 4 parts by weight, beeswax 2 parts, and tallow 1 part; or, resin 4 parts, beeswax 1 part, and tallow 1 part. Break up the resin and beeswax into small pieces, place in a pot with the tallow on top of them, and melt together over a slow fire. Pour into a bucket of cold water to cool and pull with greased hands until it assumes a light color. This makes a solid wax for grafting and some forms of budding. To saturate the muslin referred to above wind it around a stick and place it in the melted wax when not too hot. When cool enough to handle the muslin may be torn into strips about half an inch wide.

at the top instead of at the bottom of the vertical cut in the bark of the stock.

### THE ORANGE ON OTHER ROOTS.

In some citrus countries it has been found a distinct advantage to bud oranges upon seedlings of other species. Each species of citrus has its peculiar adaptations to climate and soil, which may be taken advantage of by the propagator who wishes to use them as stocks upon which to bud. In sections where this class of fruit has long received careful attention the matter of desirable stocks for certain localities and species has been fairly well worked out. For Hawaiian conditions this has not been done;[a] hence it is possible only to state, in a general way, the characters of different stocks.

*The sweet orange*[b] is itself a very satisfactory stock for average conditions, but is being largely abandoned in districts where the foot-rot,[c] or gum disease, is prevalent because of its extreme susceptibility to this malady. Since this disease is present in the Hawaiian Islands, the above fact should not be forgotten, particularly if it is intended to plant on low and rather damp land. The disease, however, is not prevalent in Hawaii; and unless it should greatly increase, the sweet orange will doubtless be used as a stock. It is not thought to be quite so deep rooted as some other species, which would not be to its advantage in deep soils on the dry sides of the islands.

*The pomelo*, or grape fruit, is a promising stock for Hawaiian conditions. It produces exceedingly vigorous growth, will probably stand more dry weather than the sweet orange, and is resistant to the foot-rot disease.

*The lime* has been used to a limited extent as a stock and affords peculiar advantages if it is desired to grow a few oranges on rocky or dry soil.

*The sour orange* (*Citrus aurantium amara*) and the rough lemon (*C. limonum*) have proved very popular in Florida, the former for the damp soils, the latter for higher and dry soils. They would probably prove satisfactory stocks for Hawaiian conditions. The rough lemon produces a more vigorous growth in the bud worked upon it than even the pomelo.

### LAYERING.

Another method of propagation, which is often very convenient for use in the home garden, but which is of no importance commercially, is that known as "air layering," or "Chinese layering." This consists in removing a ring of bark from one of the branches, or partly

[a] This station is now undertaking work of this character, which must be continued through several years before reliable results can be obtained.

[b] The sour orange is an entirely distinct form, not common in Hawaii.

[c] See "foot-rot," or mal-di-goma, page 22.

severing it, and surrounding the wound with moist soil until roots are formed. For this purpose select a branch conveniently located and about 1½ inches in diameter. Remove a ring of bark about as wide as the diameter of the branch. Surround about 7 or 8 inches of the branch at the girdled point with soil, held in place by being bound around with sacking or by a box which has been previously constructed for the purpose with openings on the sides to admit the branch (fig. 1). The soil must be kept constantly moist. When the roots have formed and filled the soil cut back the top, cut off the branch below the ball of soil and plant it, without removing the wrapping, if the latter be sacking or any material which will decay rapidly in the soil.

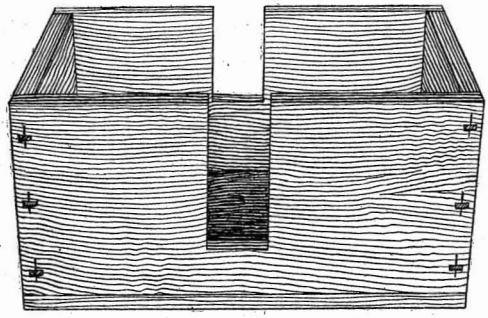


FIG. 1.—A box prepared for use in layering.

It is much simpler to practice ordinary layering by bending one of the lower branches to the ground, where possible, but most of the orange and other citrus trees in this country are headed so high that this would be impracticable. The only advantage of any method of layering is that a few bearing trees may be produced more rapidly than by planting the seed and awaiting its growth for budding.

## REMOVING THE TREES FROM THE NURSERY.

This must be done with special care. They should be dug up with as little injury as possible to the root system, and it is imperative that the roots be kept moist until they are safely replaced in the ground. It is a good practice to "puddle" the roots by dipping them in a puddle of thick mud and water. "Balling" the roots of citrus trees is a practice which entails some extra trouble, but the results attained are often sufficient to warrant even greater expense. This consists in removing each tree with a ball of soil containing the roots. To do this, dig a trench 18 inches deep along one side of the row of trees and about 6 inches away from them. Remove the surface soil down nearly to the first lateral roots and then, with a sharp spade, cut down on the three remaining sides, severing all the roots. From the trench side the tap-root may be cut off and the tree carefully lifted and placed upon a grain sack. The corners of the block of earth are then rounded off and the ends of the sack are brought up about the ball and tied to the trunk. A rope is also run around the ball and under it. The tree may then be carried to its destination and planted without removing

the sack, which will soon decay in the soil. Citrus trees may, in this way, be transported long distances with comparative safety.

Citrus trees, in these islands, may be moved at any time when they are dormant, if water is available. It will be understood that these trees do not grow continuously during the summer, but make several flushes of new leaves through the year, resting between each growth.

## PLANTING THE GROVE.

### LINING AND STAKING.

It is important that the trees be set in straight lines for business-like and neat appearance and for convenience in tillage. There are various methods of arranging the trees, but the simplest is that known as the rectangular system. To use this system, determine upon a base line for the first row, and parallel to which all the rows of trees are to stand. Standing at the end of this row, fix upon a line at right angles to this base line. This may be done by nailing together two 10-foot boards at right angles, by use of a square, and bracing them with a third board. Place this device upon the ground so that one side of it will be exactly on the base line. The other side will determine the rows as they run crosswise. Place straight stakes along both these rows at the distances at which the trees are to be planted, and repeat the operation for the remaining two sides. These stakes all around the field will determine every row. The rows should now be completed by setting stakes accurately at the proper distances, a stake to mark the place for each tree.

### DISTANCES.

Oranges may be planted from 20 to 30 feet apart, according to variety, soils, and personal taste. It is desirable to have a greater distance between the rows than between the trees in the row.

### DIGGING THE HOLES.

If the whole field has been thoroughly and deeply prepared, as it should have been, it will only be necessary to dig holes of ample size to admit the root system without cramping. If there has been any neglect in preparation, much larger holes will be required. When

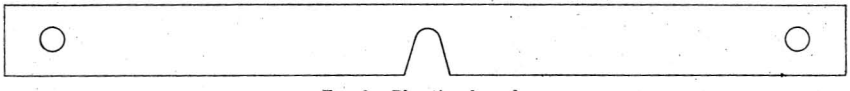


FIG. 2.—Planting board.

the hole is dug, the stake must of course be removed, and in order to mark the exact point where the tree is to be placed, a planting board is used (fig. 2). This is made of a board about 4 inches wide and 5 to 5½ feet long. A hole is made in each end, and exactly midway between

these two and on the edge of the board a notch is cut. Place this board on the ground with the tree stake in the central notch. Then put a wooden pin or short stake in the hole at each end of the board. Raise the board and the tree stake may be removed. When the tree is to be set, place the planting board down again with the pins through each end. The trunk of the tree must occupy the central notch of the board.

### SETTING THE TREE.

This must be done with care. If its roots have not been balled and sacked, some will be more or less dried and some may have been bruised. These should be cut back to sound and living wood before the tree is set out. Placing good surface soil in the bottom of the hole, set the tree upon it and spread out the roots so that they will occupy their natural position as nearly as may be possible. The tree must not stand deeper in the soil than it did in the nursery. Many trees are killed or stunted in these islands by being planted too deep. Fill in the soil gradually and press it about the roots, but not too tightly, unless it be a very light soil. If water is available, it is well to settle the soil about the roots by its use, but, in this case, tramping must not be done on the wet soil.

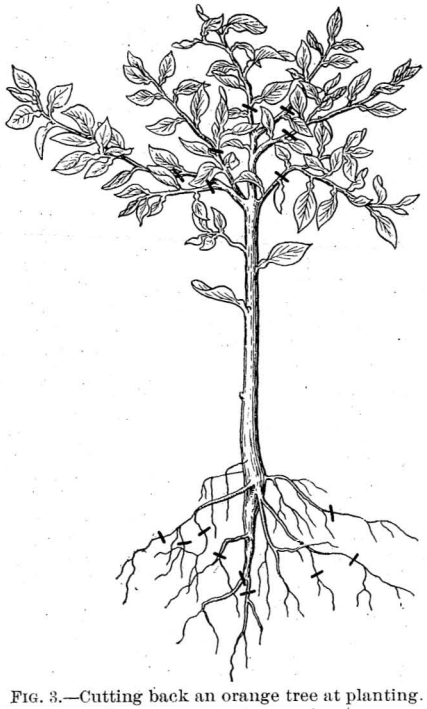


FIG. 3.—Cutting back an orange tree at planting.

### CUTTING BACK THE TOP OF THE TREE.

Cutting back is necessary, unless the tree has been removed with a large ball of earth. It has lost a large part of its root system in being moved and can not support the whole top. This pruning may be done either before or after planting. The main stem or leader of the tree should be cut back to a bud or branch, about 2½ feet to 3 feet from the ground and the side branches should all be cut back, more or less severely, according to the injury which has been sustained by the root system (fig. 3).

## TILLAGE.

The orange requires good, clean tillage.[a] If weeds and grass are allowed to occupy the ground during the period of growth the grove will suffer. In the matter of plowing there is a difference of opinion. Most orange orchards, however, are plowed at least once a year. Those that are not plowed are constantly stirred to almost as great a depth by the use of very effective harrows and cultivators. The harrow or cultivator should be used often enough to keep the surface soil loose.

In California it has been found a distinct advantage to vary the depth of tillage from year to year, thus avoiding what is known as "plow sole," or "hard pan," a hard and impervious layer of soil which sometimes forms when the soil is continuously tilled to the same depth.

## IRRIGATION.

### AMOUNT OF WATER.

All citrus trees require liberal amounts of water. The exact quantity necessary can not be stated, since it will vary with the character of the soil, the distribution of the rainfall, and the care taken in its conservation in the soil. In California[b] it may be said in general to vary from 24 to 44 inches in depth per year, including precipitation and irrigation, but it is carefully applied and conserved so as to make the very best use of it. These figures must be regarded not as a prescription, but simply as a standard of measurement for varying conditions. The number of applications into which a given amount of water will be divided also varies. In California the citrus orchards are irrigated from three to eight times per year. The best practice in these matters can be determined only by the grower himself after a study of his local conditions. In some parts of the islands no irrigation will be necessary, but in such localities it will be especially important to conserve moisture carefully as a dry time approaches.

### METHOD OF APPLICATION.

Perhaps the simplest method for the application of irrigation water is that known as the "furrow system," which consists in plowing a number of furrows in the spaces between the rows of trees and in turning the water into these from the more permanent ditches or flumes which run along the ends of the rows.

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[a] For some of the advantages of tillage in general, the reader is referred to Bulletin No. 7 of this station, p. 20.

[b] Wickson: California Fruits, p. 169.

Tillage should follow irrigation as soon as the land is dry enough to admit of it.[a]

## FERTILIZATION.

Citrus trees require the liberal use of fertilizers, unless the soil be unusually rich. Few fruit trees show such marked results from the quantity and kind of fertilizers used; but it must be constantly remembered that fertilizing is but one of the links in the chain of good culture and will be quite useless if tillage, moisture supply, and other essentials be neglected.

No prescription can be given for fertilizing which will fit all cases, but a few guiding principles may be stated. As in the case of all fruits, the same proportions of fertilizing ingredients should not be used on bearing trees as on young orchards which have not yet begun to produce fruit. Trees which should be growing rapidly but have not arrived at the bearing age require relatively large amounts of nitrogen and much less potash than those producing heavy crops. The latter require a higher percentage of both potash and phosphoric acid in the mixture. In Florida the following proportions have proved popular:[b]

For young trees: Phosphoric acid, 6 per cent; potash, 8 per cent; nitrogen, 4 per cent.

For producing trees: Phosphoric acid, 8 per cent; potash, 12 per cent; nitrogen, 3½ per cent.

A ton of such a fertilizer might be constituted as follows:

*Fertilizer mixture for oranges.*

| Constituents. | For young trees. | For bearing trees. |
|---|---|---|
| | *Pounds.* | *Pounds.* |
| Acid phosphate | 800 | 1,066 |
| High-grade sulphate of potash | 314 | 470 |
| Nitrate of soda | 250 | ..... |
| Sulphate of ammonia | 190 | 333 |
| Makeweight[a] | 446 | 131 |
| | 2,000 | 2,000 |

[a] Makeweight is material which has no fertilizing value, but which must necessarily be used if certain proportions such as the above are to be maintained in the mixed fertilizer.

This must not be regarded as a prescription for Hawaiian conditions, but will illustrate the point to which reference has just been made. Only by careful experiment and observation can the grower learn the exact needs of his citrus orchard.[c]

[a] For fuller instruction regarding irrigation, the reader is referred to U. S. Department of Agriculture, Farmers' Bulletin 116, which may be had upon application to the Secretary of Agriculture, Washington, D. C.

[b] Hume: Citrus Fruits and Their Culture, p. 312.

[c] See Hawaii Experiment Station Bul. 7, pp. 25–27.

An abundant supply of nitrogen will be indicated by a good growth and dark-green foliage. An excess of nitrogen, accompanied by a lack of potash, is manifested by rank growth and comparative barrenness, and, in the fruit, a thick rind and abundant rag.[a] Liberal supplies of potash tend to greater fruitfulness, thinness of rind, less rag, and better keeping qualities.

The fertilizing ingredients may be bought unmixed or they may be mixed to order at the factory. Sulphate of potash is usually preferred to muriate. Acid phosphate is a good source of phosphoric acid. As to the best source of nitrogen, experiences differ. In California, organic sources, such as dried blood, tankage, and stable manure, have proved satisfactory, as well as the chemicals nitrate of soda and sulphate of ammonia. In Florida, on the other hand, the use of organic nitrogen has proved a prolific source of die-back (see p. 24) and other troubles and is being abandoned. Leguminous cover crops may, however, often be used as a cheap and very satisfactory source of nitrogen. These do not seem to have produced the disastrous results in Florida which have followed the use of other organic fertilizers.

## COVER CROPS.

Cover crops, if judiciously used, may be a very decided benefit to citrus orchards. In fact, they will, in a long term of years, be found necessary to maintain the fertility of the soil. Constant, clean culture would in time exhaust the soil of its supply of humus[b] and render it unable to retain adequate moisture. Humus is also a source of nitrogen supply, and when leguminous plants are used as cover crops very considerable amounts of this most expensive of commercial plant foods are added to the soil.

In the use of cover crops, however, good judgment must be exercised. It will not do, for example, to plant such crops in a citrus orchard at the beginning of the dry season, unless abundant water for irrigation be available, since they make large demands for moisture. If planted at the beginning of the wet season, there is likely to be enough moisture to supply both trees and legumes, and the latter may be plowed under before the approach of dry weather. It has been very reasonably suggested by some that in a tropical climate it may be better to cut a cover crop and allow it to dry and partly rot before plowing it under, there being thus less danger of producing acidity in the soil. The best plants to use for this purpose must be determined by experiment in each locality. Cowpeas, velvet beans, lablab beans, and lupines have all done well in parts of these islands. The cowpeas are sometimes attacked by a species of aphis.

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[a] The tough, fibrous part of the interior of the fruit.

[b] Organic matter in the soil.

## PRUNING.

Orange and other citrus trees, except the lemon, require little pruning after the head has been properly formed. It is of great importance that the tree be given a proper shape by judicious pruning and pinching during the first years of its orchard life. The aim should be to secure a low-headed, symmetrical tree, of upright growth, covered with a compact, but not crowded, wall of foliage. Figure 4 illustrates the desired form to be attained. To secure this shape, begin when the tree is first set out. Its main stem or leader should then be cut back to within about 2½ or 3 feet of the ground. The laterals may be treated in either of two ways. They may be allowed to start and grow as low as 1 foot from the ground, with a view to gradually removing them later up to a height of 2 feet, after these lower ones have borne the first fruit, or from the start all branches below 20 inches or 2 feet may be suppressed. If the tree grows very rapidly it will often be necessary to pinch back the new growth to prevent the drooping habit, which is acquired by the young shoots becoming too long and heavy to support their own weight before woody tissue has been formed. During this formative period, and in fact throughout the life of the tree, any ambitious branches which tend to shoot out far beyond the others should be kept back. Otherwise the tree will lose its symmetrical form and become "shouldered."

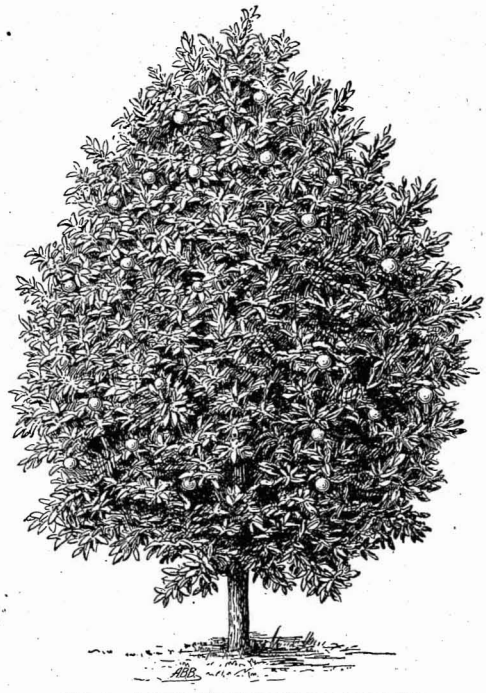


FIG. 4.—A desirable form for an orange tree.

Dead twigs in the fruit-producing area should be removed, and it is generally recommended also to cut out all dead branches in the interior of the tree. If the orchard has long been neglected and given over to the attacks of scale insects, some thinning out of the branches will be necessary before effective spraying can be done. If this condition has become greatly aggravated, it may be better to cut off all the main branches a short distance from the trunk and allow the tree to form a

new head, which it will do very rapidly and will soon again be in condition for fruit bearing.

With the exceptions noted above, the orange and all citrus fruits but the lemon will require littie pruning.

When it is necessary for any reason to remove a branch, it should be so done that the wound will rapidly heal by the growth of new tissue

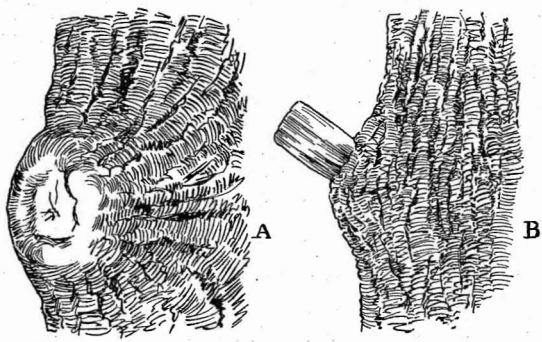



FIG. 5.—Results of correct and incorrect pruning: A, correct method, after two years; B, incorrect method.—From U. S. Dept. Agr., Farmers' Bul. No. 181.

from under the surrounding bark. The cut should be made with a sharp knife or pair of pruning shears, or with a saw if the branch is a large one. If the saw is used, it will aid the healing to make the cut smooth by means of a sharp knife. The direction and position of the cut are of vital importance. Figure 5 (at B) illustrates a very com-

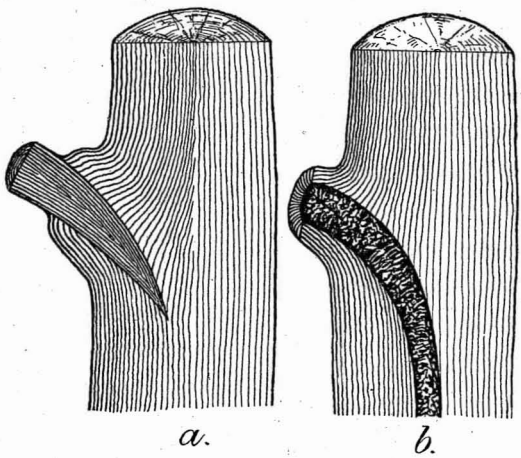



FIG. 6.—Progress of decay due to improper pruning: *a*, dead stub; *b*, decay of heart.—From U. S. Dept. Agr., Farmers' Bul. No. 181.

mon but disastrous method of pruning. The branch was cut so far from the course of the flowing sap that healing was impossible and decay soon began there and continued into the body of the tree, as shown in figure 6. In figure 5 (at A) may be seen the proper direction

and position for the cut, with the result attained. It should be as close as possible to the trunk or larger branch, to which also it should be parallel. If the wound is large, some dressing should be applied, and nothing gives more satisfactory results than lead paint.

## GATHERING AND MARKETING THE FRUIT.

### THE BEARING AGE.

Budded trees should begin to bear a small crop two or three years after setting out in the orchard. They will then be about six years old from seed or four years from budding.

### CUTTING THE FRUIT.

Citrus fruits should not be pulled from the trees as are deciduous fruits. The stems must be cut close to the fruit by means of clippers made for the purpose, and which may be purchased at small cost. Great care is necessary in handling to avoid even the slightest bruising, which though it may not be apparent at first would be conspicuous later, and injure the sale and keeping qualities of the fruit. Oranges should be well matured before picking. Some varieties should not be allowed to remain long on the trees after they have arrived at this stage. Others allow of more latitude in the time of picking.

### WASHING.

It is very often necessary to wash the fruit to remove sooty mold (see p. 23), dust, or an occasional scale insect. This may be done with an ordinary brush. There are simple machines for the purpose commonly used where citrus fruits are grown on a large scale. It should be done with care, so that the surface of the rind will not be broken or injured. Sometimes fancy fruits are polished with a soft flannel cloth or other such material.

### CURING.

When oranges are taken from the trees the rind is filled with moisture. It is necessary to hold them for several days before packing to allow the excessive moisture to evaporate. This is known as curing. The fruit is spread out in shallow bins or in small, open boxes, and kept where there will be a free circulation of cool, dry air. When thus cured the rind becomes shrunken and leathery, and will yield without bruising to the pressure which is necessary in packing. After this curing process is complete, bruises which occurred in picking may often be detected and the fruit thrown out. A further advantage is that, there being less moisture escaping in the shipping case, the loss from decay in transit is considerably reduced.

### PACKING.

Modern fruit markets demand that fruit of any kind be well graded. Large and small specimens or those of different varieties should never be placed in the same package. Only clean, smooth, uniform fruit should be placed before the buyer. The importance of this can not be overestimated. If oranges have become russet in color by the attack of the rust mite (see p. 27) they must be placed upon the market in a separate class and be so labeled. After being wrapped with tissue paper of good quality the fruits are placed in the box, there being a definite number of a given size in each package. The standard box in California is 11½ by 11½ by 26 inches, divided into two equal compartments by a cross partition. When the last layer of fruit is placed it should project about three-quarters of an inch above the edges of the box. The cover is then put on top and brought down in place by means of a lever. Though there are machines for the purpose in the market, a simple home contrivance will do the work satisfactorily. Nail a piece of 2 by 3 against the wall about on a level with the top of the box, and place the lever under this and over the box. A frame should be placed under the lever to equalize the pressure on the ends of the cover, and on the center also if it is intended to nail the cover at this point. Nail the box securely, label it truthfully, and it is ready for shipment.

## WORKING NEW VARIETIES INTO OLD TREES.

It is often desired to work over old trees with new varieties. It is now becoming very common to insert buds into the old bark of the main branches, but this requires special treatment, and for the beginner it would probably be best to follow the older method, which consists in cutting back the main branches a short distance from the trunk and inserting buds in the new growth which starts out. This budding may be done as with nursery stock (see p. 9).

## VARIETIES OF ORANGES.

The variety problem is a local factor in any fruit industry. Varieties which are eminently successful in one district may give poor satisfaction in some other place equally well adapted to the industry. As an example of this, among citrus fruits the Bahia or Washington Navel orange may be cited. This variety, which, by its fine quality, has become the leader in California, has had very indifferent success in Florida. Some varieties, however, have a wide range of adaptability. The Valencia, St. Michael, and Maltese Blood appear on lists of desirable varieties both in Florida and California.

So little attention has been given to the industry in these islands that no list of desired varieties for each section can be recommended with great confidence. The following varieties are reported to have done well in several parts of the islands: Mediterranean Sweet, St. Michael, Valencia, Bahia or Washington Navel, and several varieties of Mandarins, including King and Satsuma. A variety grown on Kauai by Aubrey Robinson, esq., produces a fruit of unusually fine appearance and excellent flavor. The coloring is, perhaps, superior to that of any other variety which the writer has seen in Hawaii, and this is an important consideration, since many of the fruits locally grown are lacking in this particular. The name of this variety is not known. It is thought by Mr. Robinson to have been introduced from the Azores.

### HAWAIIAN VARIETIES.

It may seem a little startling to speak of Hawaiian varieties of oranges. Yet there are such, some of which have sufficient excellence to place them ahead of any known variety from abroad for the local home garden. They lack names. These are simply seedlings which have been grown here. When budding shall have become more common in the islands, some of these varieties will be named and propagated and their qualities will be more widely known and recognized. Other good seedling varieties also will doubtless develop, some of which may prove superior to the introduced varieties, even for commercial purposes, though the requirements of a commercial fruit are ever becoming more rigid. The history of many fruit industries reveals the fact that varieties of local origin are best for the conditions in which they originate.

This station will take up the work of testing varieties from abroad and also of propagating Hawaiian varieties of merit.[a]

## DISEASES.

### FOOT-ROT, OR GUM DISEASE.

This is perhaps the most widespread of any citrus disease. It has been noticed in these islands, but it has never attracted general attention. The disease first manifests itself by the presence of drops of gum on the trunk of the tree near the base. The inner bark or affected portion becomes watery and emits a disagreeable odor. The tree builds a line of new tissue about the diseased spot, the old bark dries up, and the decay extends into the wood. If the disease is not checked the tree assumes a general unhealthy appearance with yellowish-green

[a] The station will be glad to learn of any variety of marked superiority in any part of the Hawaiian Islands.

leaves, but at first there may be a larger crop of fruit than usual. The cause of the disease is not definitely known, but a fungus is generally regarded as responsible for its presence.

The measures for the control of the trouble are both preventive and curative. A very effective means of avoiding the disease is made possible by the fact that some species of citrus are decidedly resistant to its attacks. In setting new orchards where the malady is prevalent, these resistant species are used as stocks upon which to bud the orange. In Hawaii the pomelo would be a readily available stock for this purpose and is known to be decidedly resistant to the disease. The rough lemon and sour orange are still more resistant, but would not be so readily available, and have not been sufficiently tested in Hawaii to warrant their use except in an experimental way.

Diseased trees may be treated by carefully removing the soil from the crown roots for a distance of 2 or 3 feet from the trunk and cutting away the bark and diseased portion of the wood. Then apply with a brush or spray pump a wash composed of equal parts of water and crude carbolic acid. Leave the roots exposed until the tree has recovered. If the trees are crowded, cut away or remove some and let in light. Use stable manure sparingly, if at all.

### RIPE-ROT (*Penicillium italicum*).

Ripe-rot of citrus, as of many other fruits, is due to fungus attack. The fungus gains entrance through some injured part and rapidly renders the fruit unsalable. The remedies consist in careful handling to avoid bruising, thorough curing, and the destruction of decaying fruit.

### SOOTY MOLD (*Meliola camelliæ*).

It is this fungus or allied species which causes the blackened appearance of the leaves, fruits, and twigs of the different species of citrus, mangoes, guavas, and avocado pears. It does not live in the tissue of the plant, but draws its life from a sweet substance called honey-dew, which is deposited on the surfaces of the plant by aphids and scale insects. It is nevertheless a decided detriment to the plant, because of the covering which it makes, thus interfering with the functions, especially of the leaves. The remedy for this trouble consists in destroying the insects which produce the honey-dew. (See p. 25.)

### LICHENS.

In the moister sections of the islands these forms of plant life, which somewhat resemble moss, are to be found growing upon the trunks and branches of citrus trees. They may be destroyed by the

use of Bordeaux mixture[a] applied with a spray pump or a scrubbing brush.

### DIE-BACK.

This is a disease which is not the result of any definite organism, so far as known, but seems rather to be due to abnormal conditions of the soil. It manifests itself by the young shoots becoming yellowish, followed by reddish-brown stains and the dying back of the new twig for several inches. The tree makes repeated efforts to send out new growth, but this, in its turn, dies back also. The fruit cracks open and falls.

The disease has been prevalent in Florida and has caused considerable damage in California. The malady in California is generally attributed to the placing of citrus trees on soil unsuited for their culture by the presence of hardpan near the surface, or to other conditions resulting in poor drainage. In Florida a more prolific source of the trouble seems to have been the use of organic nitrogenous manures. The disease has been reported in several parts of the islands. If trees are affected with this malady, the grower should look to the condition of the roots and had better apply chemical fertilizers only, using nitrate of soda and sulphate of ammonia as sources of nitrogen.

### SCAB—LEMON SCAB, OR VERRUCOSIS.

This is a disease which affects chiefly the lemon, but is also found upon the sour orange, a few varieties of mandarins, and some other citrus species. It is characterized by conical elevations on the leaves, twigs, and fruits. On the leaves the elevations appear on the upper surface and are accompanied by corresponding depressions on the lower side. The elevation is crowned by a warty growth, where the presence of the fungus is very manifest. Similar warty cones grow

[a] To prepare Bordeaux mixture proceed as follows:

Place 6 pounds of bluestone (copper sulphate) in a sack and suspend in a barrel or other wooden or earthen vessel containing 25 gallons of water. In another barrel or tub slake 4 pounds of quicklime by adding water very slowly at first. Dilute with water the paste thus formed until the total bulk of milk of lime is 25 gallons. Pour the bluestone solution and the milk of lime, at the same time, into a third barrel so that the two will unite in a single stream as they fall. Strain the mixture through a sack and it will ordinarily be ready for use. A test, however, should be made to determine whether there is any danger of injury to the foliage. This may be made by simply inserting the clean blade of a penknife into the mixture and retaining it there for a minute or two. When withdrawn, if there is no deposit of copper on the blade the mixture is safe for ordinary use. If copper should appear, more milk of lime must be added.

upon the surface of the fruit, giving it a distorted and roughened appearance.

The disease is peculiar to moist localities. For this reason it has never become troublesome in California lemon orchards, where the climate is dry during the growing season, but in Florida it has caused much damage. It is quite common in Olaa, Hawaii.

The disease is the result of a fungus (*Cladosporium* sp.). It is controlled by the use of Bordeaux mixture or the ammoniacal solution of copper carbonate, the latter having given the best results. This solution may be prepared as follows:

Take 5 ounces of copper carbonate and stir up with about a pint of water to a thick paste; then dilute with 1½ gallons of water in a wooden pail. Stir vigorously and at the same time add slowly 2 pints of strong ammonia[a] or 5½ pints of weaker ammonia water.[b] Stir until all is dissolved, or at least all but a few granules, and then dilute with water to 50 gallons.

Apply this solution or the Bordeaux mixture as a fine spray, just after the petals[c] of the first flowers have fallen, and again two or three weeks later. A third spraying should be given after the lapse of another two or three weeks. Occasionally it may be necessary to continue the application every few weeks throughout the season. By keeping a careful watch of the growing fruit to see whether new elevations are appearing the grower can determine when it is necessary to spray.[d]

## INSECTS AND OTHER ENEMIES.[e]

There are many insect enemies in all citrus regions. Hawaii is no exception to this rule, and yet these islands are fortunate in having no insect enemy of citrus fruits which can not be controlled by the thorough, business-like application of modern methods of combating insects.

### THE PURPLE SCALE.

The purple scale (fig. 7) is the most prevalent insect enemy of the citrus species in the islands. It infests the leaves, fruit, and bark and

[a] Aqua ammoniæ (28 per cent) of druggists.

[b] Aqua ammoniæ (10 per cent) of druggists.

[c] The white, conspicuous, leaf-like parts of the flower.

[d] For further information regarding citrus diseases, the reader is referred to Bulletin No. 8, Division of Vegetable Physiology and Pathology, U. S. Department of Agriculture, Washington, D. C.; also Bulletin 52, Bureau of Plant Industry, of the same Department.

[e] For a more complete statement see "Scale Insects and Mites on Citrus Trees," U. S. Dept. Agr., Farmers' Bul. 172, which may be had upon application to the Secretary of Agriculture, Washington, D. C.

may be readily recognized in the adult stage as a purplish body, in shape somewhat like a miniature oyster shell. The young are exceed-

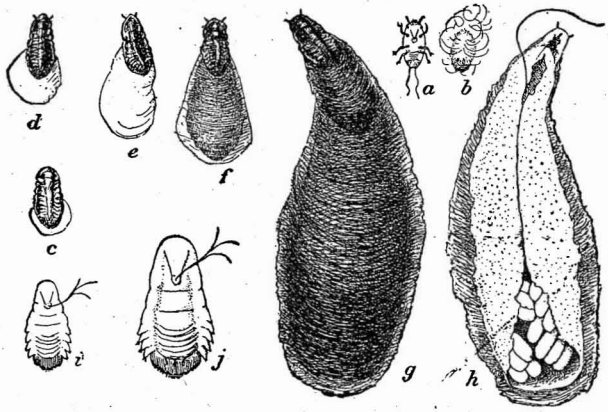



FIG. 7.—Purple scale (*Mytilaspis citricola*), showing different stages of female: *a*, newly hatched larva; *b*, same with first waxy secretion; *c* to *f*, different stages of growth; *g*, mature scale; *h*, same inverted, showing eggs; *i* and *j*, half-grown and full-grown female insects removed from scale—all much enlarged (original).—From U. S. Dept. Agr., Farmers' Bul. 172.

ingly minute and often escape the notice of any but a careful observer. Yet it is in this stage that they are most readily destroyed.

### MEALY BUGS.

Two species of mealy bugs are found upon citrus trees in Hawaii. One of these, which also infests other plants, is found chiefly upon the terminal twigs, interrupting their growth and causing them to become twisted. It may be recognized as a cottony-like mass, on the end of the growing part, and is often accompanied by ants. The other species inhabits various parts of the tree, but is of less practical importance in the islands.

### ORANGE APHIS OR "BLACK FLY."

The orange aphis or "black fly" of the orange is common upon the new, fresh growth of the orange and other species of citrus trees. It can hardly be mistaken for any other common insect on these trees.

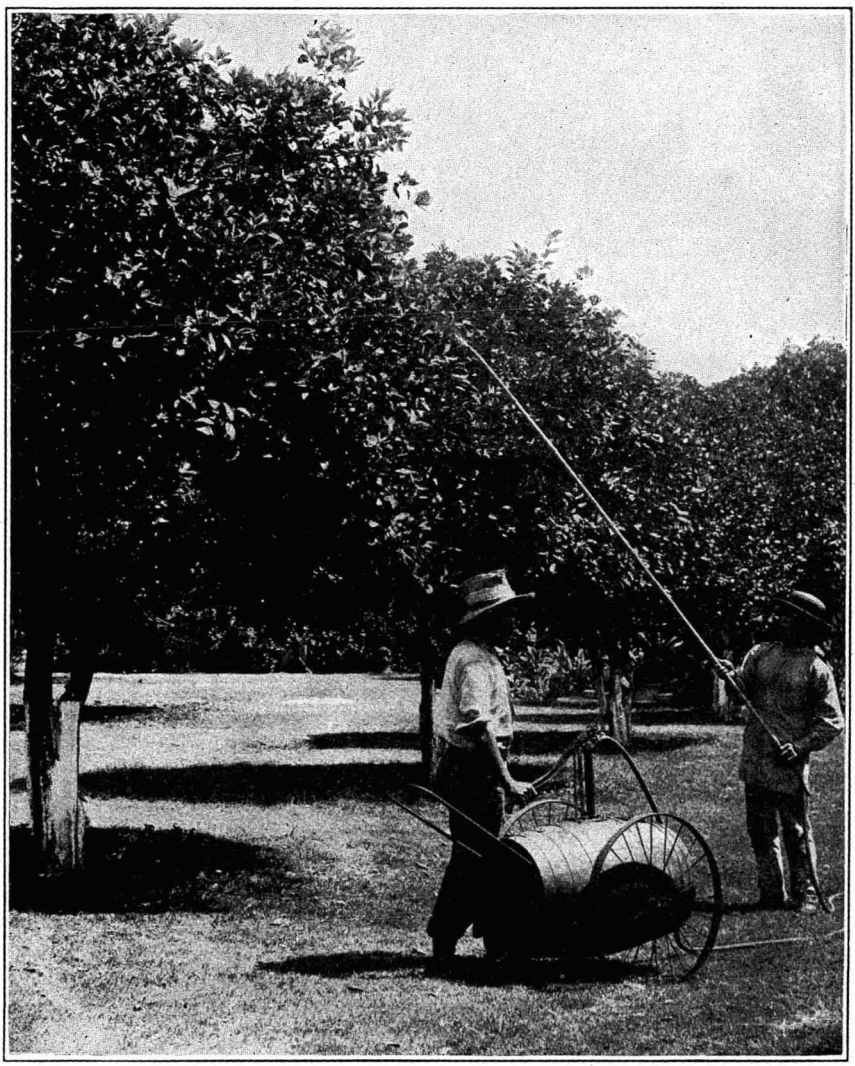
### REMEDIES.

The standard remedies for all of these pests and for other scales or sucking insects are the oil washes. The most common of these, kerosene emulsion, is prepared according to the following formula:

*Kerosene emulsion.*

| | | |
|---|---|---|
| Kerosene | gallons.. | 2 |
| Whale-oil soap (or 1 quart soft soap)[a] | pound.. | ½ |
| Water | gallon.. | 1 |

[a] Any laundry soap will serve the purpose if whale-oil soap is not obtainable.



A BARREL-SPRAYING OUTFIT MOUNTED ON WHEELS, FOR SPRAYING IN LARGE YARDS OR SMALL ORCHARDS.

The soap, first finely divided, is dissolved in the water by boiling and immediately added boiling hot, away from the fire, to the kerosene. The whole mixture is then agitated violently while hot by being pumped back upon itself with a force pump and direct-discharge nozzle throwing a strong stream, preferably one-eighth of an inch in diameter. After from three to five minutes' pumping the emulsion should be perfect and the mixture will have increased from one-third to one-half in bulk and assumed the consistency of cream. Well made, the emulsion will keep indefinitely, and should be diluted only as wanted for use. * * *

HOW TO USE THE EMULSION.

During the growing period of summer, for most plant lice and other soft-bodied insects, dilute the emulsion with from 15 to 20 parts of water; for red spiders and other mites, the same, with the addition of 1 ounce of flowers of sulphur to the gallon; for scale insects, the larger plant bugs, larvæ, and beetles, dilute with from 7 to 9 parts of water; apply with a spray pump.[a]

Plate II illustrates a barrel outfit for spraying. It is mounted on wheels, and is convenient for spraying small orchards or the trees in a large yard. Smaller appliances for use where there are only a few trees are figured in Bulletin No. 3 of this station.

## ORANGE RUST MITE (*Phytoptus oleivorus*).

The orange rust mite, which is so small as to be practically invisible to the naked eye, is the cause of russet oranges. It pierces the surface of the rind to secure the essential oils contained therein, and as a result of this injury the rind of the orange becomes a russet color, while that of the green lemon becomes more or less silvery. It is therefore sometimes called the lemon "silver mite." Oranges so affected are usually of even better flavor than those that are bright, but in the market they sell at lower prices because they are not so attractive in appearance.

TREATMENT.

Sulphur is the most effective remedy against this pest. It may be dusted on the trees as a powder, either by itself or with lime, in equal proportions, or it may be applied in a spray. If it is intended to use it in the powdered form, there are very inexpensive machines on the market for the purpose, as well as larger ones for more extensive work.

If used as a spray, the stock solution may be prepared according to the following formula:

*Sulphur-soda spray.*

| | | |
|---|---|---|
| Flowers of sulphur | pounds | 20 |
| Pulverized caustic soda (98 per cent) | do | 10 |
| Water | gallons | 20 |

With a small quantity of the water mix the flowers of sulphur into a paste. Add the caustic soda, which will cause boiling and the lique-

[a] U. S. Dept. Agr., Farmer's Bul. 127.

faction of the mass. More of the water must be applied gradually, to prevent burning, until finally the whole 20 gallons have been used. One gallon of this stock solution must be diluted with about 25 gallons of water before applying to the trees. If other insecticides are being used, this may be used in combination with them.[a]

## THE LEMON.

In most particulars the lemon may receive essentially the same treatment as that described for the orange. The methods of propagation, tillage, irrigation, etc., are the same. It is seldom grown on its own roots. In California the favorite stock for the lemon is the sweet orange seedling. The pruning of the lemon trees and the curing of the fruit are quite distinct from the practice in relation to oranges.

### PRUNING.

The lemon has not the same tendency to compactness of form as is found in the orange tree. Its habit is straggling, and if left to itself it will produce its fruit on the ends of long branches. It therefore requires a method of pruning persistently pursued if the best results are to be secured. There are several elaborate systems of pruning which are in use, but the aim of them all is to produce a compact, but not too dense, low-headed tree with a large amount of bearing surface on easily accessible branches. This is secured by cutting back the leader or main stem of the tree when it is set and forcing out stray branches, three or four of which are selected to form the framework of the tree. These in turn are persistently pinched or cut back and encouraged to assume a nearly horizontal position. Any branches that start to make a strong growth in a vertical direction are cut out. This continuous pinching and cutting back tend, however, to produce a very dense mass of branches and foliage and some thinning out becomes necessary. The general result of such systems is a low, flat-topped tree, from which most of the fruit may be gathered without the use of long ladders.

### PICKING.

Lemons are always picked green. If ripened on the trees, they lose in their characteristic acidity and become too large. They are taken from the trees when they will just fit a $2\frac{1}{4}$-inch ring, and must be clipped like an orange and handled with the same care.

### CURING.

The curing and storing of lemons is a much more prolonged and difficult process than that of oranges. Simple methods of curing may suffice when the lemons can soon be marketed, but when it is intended

[a] See kerosene emulsion, page 28.

to hold them for many months for the best markets special devices are required and the skill of one who has had experience in the business. The objects aimed at are, in part, the same as in the case of the orange, but further, the lemon must attain its proper color, the thickness of the rind must be greatly reduced, the acidity increased, and the fruit preserved in marketable condition for a long time. This is attained by holding the fruit in a dark place, in a temperature as nearly uniform as possible and with sufficient ventilation to prevent molding and decay, but not enough to cause the wilting of the fruit. Where the business is conducted on a large scale curing houses are provided. In the Hawaiian climate it will probably be necessary to cure lemons under a roof.

### VARIETIES.

There are few varieties of lemons that are successful commercially. The variety Villa Franca is probably the most extensively grown in Florida and California. The Eureka and Lisbon are also popular varieties. These have not yet been sufficiently tested to demonstrate their adaptability to different parts of the islands. The Sicily has been reported as doing unusually well in Hamakua and Olaa and probably will prove to be well suited to many parts of this Territory. Dr. N. Russel, of Mountainview, Olaa, in speaking of trees of this variety, says they "grow quickly and give excellent fruit, superior to California lemons."

### POMELOS, GRAPEFRUITS, AND SHADDOCKS.

There is some confusion in the use of the terms "pomelo," "grapefruit," and "shaddock." From the standpoint of the botanist these are simply different names applied to the same species, *Citrus decumana*, but horticulturally some distinctions may be made. The term "shaddock" is now being reserved for extremely large, coarse, and almost inedible forms of the species. They may be seen in many parts of the islands, but are practically useless, except for ornamentation and curiosity, for which purposes they are quite popular among the Chinese residents. The "pomelo" is precisely the same as the "grapefruit," with which everyone is familiar in the markets. The name "grapefruit" has arisen from the fact that they are borne in clusters like grapes in a bunch. This is the designation by which they are most commonly known. The term "pomelo,"[a] however, is the one which is now given the preference, and has been adopted by the U. S. Department of Agriculture, by the American Pomological Society, and by the State horticultural societies of both California and Florida.

[a] The spelling has been various, as pumelo, pummelo, pumelow, etc., but pomelo is now the recognized form.

## VARIETIES.

The fruits commonly seen in the markets are budded varieties and sustain the same relation to the seedling pomelos of our gardens and dooryards as do our seedling oranges to the imported varieties, such as the Navel or the Valencia. Some of our seedlings are of peculiarly fine flavor, but, because of the thickness of the rind or other faults, they fall short of the standard set for a market variety. In the future it is highly probable that seedlings will be produced which will have commercial merit, perhaps exceeding those of any introduced variety under Hawaiian conditions. There can be no doubt that the fruit, even of the seedlings now growing, can be greatly improved by the best methods of cultivation. They respond freely to judicious care in fertilization and irrigation. The thickness of the rind and the amount of rag may be materially reduced by the liberal use of potash and the limited application of nitrogenous manures.

The introduced varieties, however, have done well in these islands, but local experience has been too limited to justify definite recommendations of varieties. It is probable that little difficulty will be experienced in finding several suitable kinds, as the pomelo seems much at home in Hawaii. The following varieties are worthy of careful trial: Triumph, Duarte Seedling, Aurantium, Colton Terrace, Duncan, Marsh, Royal, and Standard.

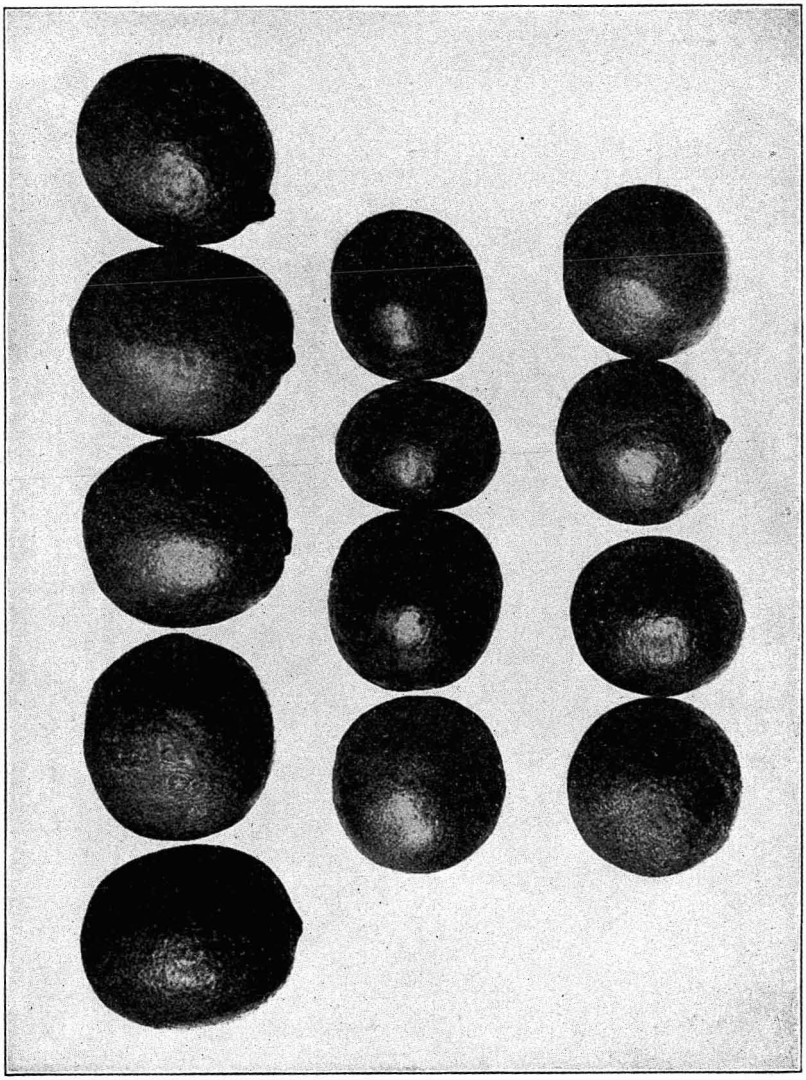
The Triumph and Marsh or Marsh Seedless are reported as having done well in parts of Oahu.

The distances between the trees need to be greater than in the case of oranges, because of the more vigorous growth made by the pomelo. Twenty-five to 35 feet will be quite close enough on good soils.

The fertilization, irrigation, tillage, picking, curing, and packing are essentially the same as described for oranges.

## THE LIME.

The lime or acid lime (*Citrus medica acida*) is widely grown within the Tropics, but because of its extreme sensitiveness to low temperatures is not at all successful in many orange-growing districts. Here in Hawaii it thrives and produces large crops of fruit. It will prosper on rather rocky soils and those too poor for orange cultivation. The propagation is usually by means of seeds only, but budding has been practiced to a limited extent, and will doubtless be used more extensively in the future. Seeds can not be depended upon to reproduce exactly the same form as that of the fruit from which it was taken, but for many of the purposes for which limes have been used uniformity of shape, color, or size is not an essential. The trees should be planted 15 to 20 feet apart.



COMMON VARIATIONS IN FORM IN THE MEXICAN OR WEST INDIAN LIME.

Limes are put to many uses. In the Tropics they are freely used as fresh fruit for the making of limeade and in the seasoning of foods. The market for the fruit in this form is increasing in the United States and the demands of the future for a lime of fine quality and appearance are likely to become increasingly stringent, hence the better forms will be multiplied by budding. At the present time, however, by far the larger number of limes are marketed in the form of so-called secondary products. Considerable numbers of them are preserved in brine and sent to Northern markets. Larger quantities are used in the manufacture of lime juice and citric acid, while essential oil is extracted from the rind. The lime juice is obtained by pressing the fruits between rollers and is usually marketed in large containers. Citric acid is obtained from the concentrated juice, which is made by boiling down in open vessels.

## VARIETIES.

Through prolonged seed propagation several more or less distinct types have been originated. In India, the home of the lime, several named varieties are known. In America, Hawaii, and the West Indian Archipelago the commonest type is that known as the Mexican or West Indian lime. Of this type there are many distinguishable forms (Pl. III), some of which are much larger and finer than the average. But few of them have been named, propagated by budding, and disseminated upon their merits.

Other varieties are the Persian and the Tahiti. The Tahiti is, in Florida, one of the most highly esteemed varieties of lime. The fruit is large, the rind of lemon-yellow color, the quality of juice excellent, and there are few seeds or none. The fruit is said to have a tendency to decay on the trees.[a] In California this variety is not a success.

[a] Hume: Citrus Fruits and their Culture, p. 143.

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